ATOMICS

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A bi-monthly journal devoted to the needs and interests of everybody concerned with the application of nuclear energy in all its various phases, in industry, in the medical and biological sciences and in the development of electrical power and heat.

ATOMICS

ANDREW W. KRAMER, *Editor*

Secret Weapons and Free Speech . . . During the past month the Atomic Energy Commission ordered the destruction of several thousand printed copies of an article by Dr. Hans Bethe which were being printed for the current issue of the Scientific American. At the same time the type for a portion of the article was removed and melted down before the run of the issue was permitted to proceed. Fortunately for the publishers, the number of copies that had been run off represented a relatively small percentage of the total run of the Scientific American.

Curiously enough, the reason for this unprecedented action on the part of the Atomic Energy Commission was not because Dr. Bethe's article discussed technical details of any atomic process or weapon. The censored material, it is reported, merely expressed Dr. Bethe's opinions concerning the destructive effects of certain atomic weapons—the hydrogen bomb in particular. Furthermore, what Dr. Bethe had said, evidently had been said by others in previously published articles. One may wonder, therefore, why the AEC took action in this instance.

The reason, as explained by the Commission, was not that Dr. Bethe disclosed classified material of any kind or, in fact, any information that had not previously been made public by others but because Dr. Bethe had once occupied a responsible position in the Manhattan project and that he had had access to classified information.

If this seemingly arbitrary action on the part of the AEC may be construed as a violation of our right of free speech, a few moments thought and consideration will show that this is not so. Even in a democracy, free speech has certain limitations and most of us, confronted with the complexities of modern industrial society, have long given up the ideal of absolute individual freedom. Both custom and law have frowned on blasphemy, obscenity, and incitement to riot, at least in public and in time of war we have greatly extended limitations on freedom both of speech and of action.

Traditionally, science has been international and completely free. Technology, or applied science, has been less so and military technology, still less so. Every scientist knows that the free interchange of knowledge and ideas is largely responsible

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for the rapid growth and vigor of science. Of course, the same thing would be true of military technology; it, too, would advance most rapidly if information were exchanged freely. We could probably make better weapons if we had free access to all the ideas of everyone in the world who was thinking of weapons and planes. But, so could our potential enemies.

We must remind ourselves that the only reason for having a military technology is to defend ourselves against attack. Therefore our object is not the best possible military technology, but a constantly maintained advantage of our technology over that of our potential enemies. As pointed out by AEC Commissioner Dr. Henry D. Smyth recently, these general principles are not new and could be applied to any military preparation in history but there are two new elements in the situation. The first is the increasing importance of technology in war and the second is the disappearance of the time gap between basic scientific research and military technology. Both of these factors are examplified in the atomic bomb.

These two elements in the situation have put us into a dilemma of the first magnitude. On the one hand, rapid progress in basic science requires free interchange of information. Thus, since military technology depends upon basic science, we must have free interchange of information. On the other hand, we want our military technology to surpass that of our enemies. We want to keep to ourselves new weapon developments on which we spend millions of dollars. These developments may depend on discoveries in science. Therefore, we must have complete secrecy in both science and technology. Either of these lines of argument appears to be logical and they provide a dilemma even before we add to it political arguments for freedom of speech.

In attempting to make the most effective compromise, the AEC has consulted with other branches of the government and has laid down two simplifying assumptions:

1. Weapons information including design, production, and stockpiles, should be kept secret.

2. Basic science should be kept free except where it is directly related to weapons.

Unfortunately, these principles are easier to formulate than to apply. There is a twilight zone of information that does not automatically fall into either catagory. In juding such information the AEC has set up a simple criterion. It asks itself: Will the release of this information help us more than it will help our potential enemies? Again, the criterion is simple but applying it is difficult.

At the present time it is the policy of the Commission to disregard almost entirely, the writings and speeches of those who have had no access to classified information. There are two reasons for this. First the Commission wishes to restrict its activities as much as possible and second, comment on such writings might reveal the very thing the Commission wants to keep secret. If a writer should happen to guess correctly in regard to some secret development, as long as he does not know that he is right no security is breached. If, however, the Commission identifies these guesses which coincide with facts by insisting on their removal, security would be breached.

This is why there has been no hint of protest from the Commission about most of the speculative articles which have been written about how a hydrogen bomb can be built, its probable effects, probable degree of suc-

cess, or the rate of progress or the rate of progress the U.S. has made in developing such a weapon. When these articles are written by people who have had no access to confidential information, the Commission makes no comment.

Now, we come to the twilight zone that is really hard to handle, the writings of people who have, or have had, access to classified data and are discussing topics related to the classified programs of the AEC. Here the Commission believes that these men share with the members of the Commission the responsibility for seeing to it that no significant information is revealed. However well acquainted these authors may be with various phases of the projects, they should realize that they themselves cannot always make sound judgment on the significance of what they have written. As pointed out by Commissioner Smyth, if there is any possible doubt in the minds of these writers, it is the wish of the Commission that they submit their articles or speeches to the Commission well in advance of publication or delivery.

It is in this last catagory that Dr. Bethe's article belonged. Dr. Bethe had once had access to considerable classified information and even though what he said about the probable effects of a hydrogen bomb might have been no different from what a dozen other writers have said, the fact that he had knowledge not accessible to the others gave his opinions a value and a stamp of accuracy not attributable to the opinions of those who had never had access to classified data.

Fortunately, in Dr. Bethe's case, the amount of expense and inconvenience involved in making the changes in his article was not as great as might have been if knowledge of the article had reached the Commission at a later time; that is, when the entire issue of the Scientific American had been run off. The fact that it did happen however, clears the air, so to speak, and the Commission's ruling and explanation makes it easier for writers and speakers to know where they stand in expressing opinions on matters of atomic energy.

Power for Atomic Accelerators

The problem of supplying power to the very large atomic accelerators now under construction is a formidible one. As described in this article one of the units now under construction will require a peak direct current of 8333 amperes at 12,000 volts. Here, is described in some detail the power supply for the great proton synchrotron to be installed at the University of California Radiation Laboratory at Berkeley.

By L. A. KILGORE
Assistant Manager, A-C Generator Engineering

J. L. BOYER
A-C Generator Engineering

C. S. HAGUE
Industrial Department
All with Westinghouse Electric Corporation, East Pittsburgh, Pa.

NUCLEAR RESEARCH has many facets reflecting developments in many related fields. One of the most important of these facets involves the tools used by nuclear physicists in their work, the development and construction of the huge cyclotrons and other types of accelerating machines which have become so necessary as ever increasing energies are dealt with. The size of these modern machines is truly enormous and the task of supplying power to them is becoming a formidable undertaking in itself. One of the larger units now under construction will require a peak direct current of 8333 amperes at 12,000 volts!

Recently a new and tremendously powerful accelerator known as the proton synchrotron has been designed and two of these machines are currently being constructed, one at Brookhaven National Laboratory and the other at the University of California Radiation Laboratory.

The Berkeley proton synchrotron, called a "bevatron" from the abbreviation "bev" for billion electron volts, will accelerate protons (positively charged nuclear particles) from their initial injection energy level of about 10 million electron volts to an energy level as high as six billion electron volts. The Brookhaven machine, called a "cosmotron," will accelerate protons to over three billion electron volts. These are new highs in energy levels when compared with the few hundred million electron volts previously obtainable.

One function of the proton synchrotron will be to facilitate further study of mesons, the short-lived particles seen in cosmic rays. Mesons are now produced by synchro-cyclotrons at Berkeley and at Rochester, but the high energy level of the proton synchrotron should greatly increase meson yields and thus advance knowledge of these key particles. In the billion-volt energy region one may expect nuclear reactions not obtainable in the laboratory with accelerators now operating. Also there is speculation on the possibility of producing heavy nuclear particles, such as proton pairs (positive and negative protons), which is analogous to the production of electron pairs at lower energies.

Basically the proton synchrotron is a giant doughnut shaped iron magnet —110 ft. in diameter, weighing upwards of 10,000 tons—the inside of which is an evacuated chamber into which the protons are injected. The protons are accelerated around this void by oscillator-governed electrodes and their path is controlled by the field of the magnet. The particles make a few million revolutions and travel about 300,000 miles in the 1.9 seconds required to attain the velocity desired for bombardment of the target. Upon reaching this high energy level, the closely grouped protons are made to strike a target placed at the edge of the vacuum chamber. Here these

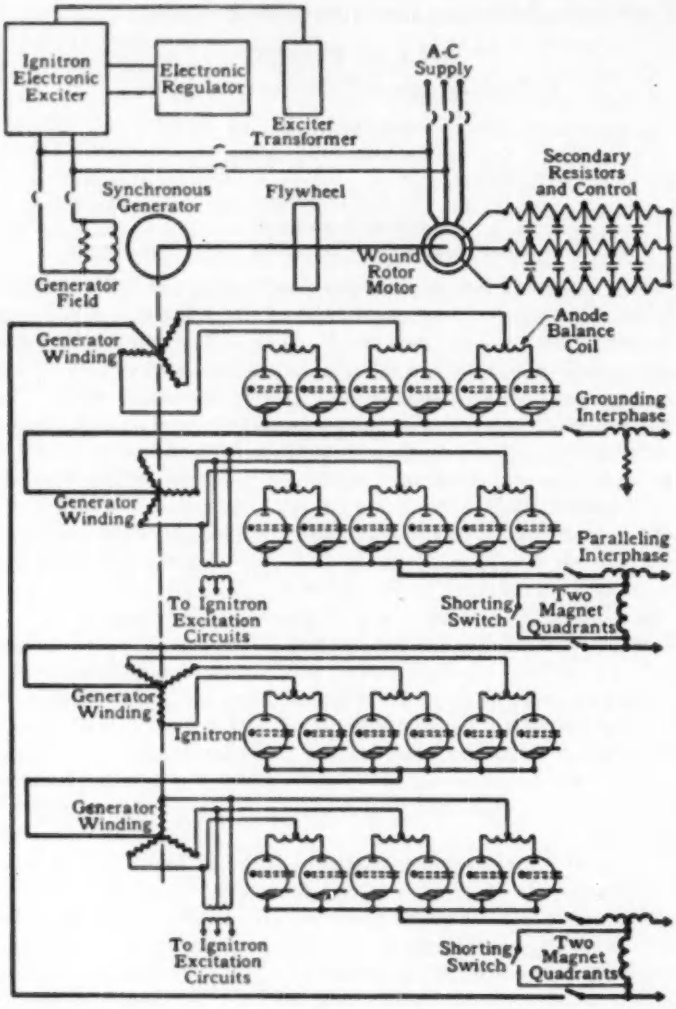

Fig. 1 Simplified circuit diagram of the main units in one half of the magnet power supply. No attempt is made to show the full wiring diagram. The portion shown is half of the complete system, an identical section is tied in where the arrows indicate (on the right side) to complete the bevatron magnet power supply

"bullets" of energy will cause transmutation or atomic disintegration of the targets at which they are aimed.

Of prime importance to the proper functioning of the proton synchrotron is the precise control of the magnetic field needed to maintain the protons in their orbit. As the higher velocities are reached, the radius of the circular path of the accelerating protons changes because of the changing mass of the protons themselves. Control of this orbital path is obtained by increasing the field strength of the magnet as the particle velocity is raised. But, because the field strength does vary, the particles can be accelerated only in groups and not in a continuous stream as in the cyclotron.

To avoid complications in frequency tracking and to insure a gradual increase in energy gain per turn, it is desirable to increase the field in a uniform manner from zero at the beginning of each accelerating impulse to a peak value just as the protons are deflected from the chamber. The current build-up time is roughly 1.9 seconds. Following this, to reset the magnet for the next proton-accelerating period, it is desirable to have the current decay period as short as possible. But to reduce the current to zero against the tremendous inductance of this magnet, the polarity of the d-c supply must be reversed.

Two systems are available for supplying such power requirements. One involves d-c generators driven by a-c motors, with generator field reversal utilized to change polarity. The other uses ignitrons, supplied by an a-c motor driving an a-c generator. The ignitrons are fired as rectifiers during the period of current build-up and as inverters during the period of current decay.

The system utilizing ignitrons has many advantages. Of foremost importance is the fact that the initial expense is less than for massive d-c generators of the required capacity. Furthermore, the polarity of the ignitron system can be reversed within 1/120 second, whereas a much longer period and a highly complex regulating system would be required to reverse the field of the d-c generator.

Complete systems for supplying magnet power for two new proton synchrotrons are being built. The larger of these units requires a peak direct current of 8333 amp at 12,000 v, with the power peak occurring at a maximum rate slightly more than 11 times a minute. To allow operation of the proton synchrotron at full capacity and also at one-half capacity, two parallel power-supply units are provided.

DIRECT-CURRENT SUPPLY

The flow of power can be visualized from Fig. 1 by following the heavy lines from the a-c supply line to the wound-rotor motor that drives a flywheel and a 12-phase synchronous generator. Each three-phase group of generator windings is connected through anode balance coils to six continuously evacuated ignitrons. The four ignitron groups are connected in series with the two sections of the magnet coil, which is divided into two parts to reduce maximum voltage to ground.

During the period of proton acceleration, the ignitrons are fired on the positive half of the voltage wave to act as rectifiers. In drawing current for the magnet coils from the a-c generator, the motor-generator-flywheel set is slowed down. The flywheel gives up energy, as the rotational velocity decreases, to maintain speed drop within the required limits. Upon com-

pletion of the accelerating period, the firing point of the ignitrons is shifted to the negative half of the voltage wave and they act as inverters to transfer the stored energy in the magnet inductance through the generator to the flywheel, where it is absorbed to return the shaft speed to normal. Also, during this period, power is being drawn from the line to return the m-g set to normal speed in readiness for the next accelerating impulse. The motor secondary resistance is controlled in such a way as to limit the motor current to reasonable values as the flywheel changes speed.

Although appreciable voltage regulation in the d-c supply is permissible, it is important that the voltage wave shape for each succeeding impulse be identical to maintain the relationship between the magnet field force and the frequency modulation of the driving oscillator. To accomplish this, the field of the generator is supplied by a small sealed-tube ignitron rectifier. The output of this rectifier is controlled by an electronic regulator acting on the firing point of the sealed ignitrons and receiving its intelligence from instrument transformers in the output circuits of the generator. This arrangement allows a variation of only one half of one percent for any point on succeeding voltage waves.

If allowed to coast, the m-g set would take several hours to come to rest. However, under certain emergency conditions the machine can be stopped within five minutes. For such emergencies a switching arrangement is provided whereby the motor primary is disconnected from the supply line, the generator-field circuit breaker is opened, and d-c output from the electronic exciter is impressed across one phase of the motor primary. In this way the energy of the rotating parts is absorbed in the secondary resistance.

As two flywheel-motor-generator units are operated in parallel, the instantaneous voltages of the a-c outputs may not be the same because of phase displacement of one generator with respect to another. Therefore, paralleling interphase transformers are required at each point where the magnet coil is connected to the rectifier units, insuring equal load division. Another interphase transformer is provided to block circulating currents at the point where the two units are connected to a common ground.

These power supplies are composed of specially designed units containing several unique features because of the problems posed by the design and performance requirements. The a-c generator, the ignitron tubes, and design of the necessary control circuits are of signal importance.

IGNITRON RECTIFIERS

These specially designed ignitron tubes are required to handle a heavy direct current at a high voltage (18,000) and be reliable on both rectification and inversion. The period of rectification is about 1.9 seconds and the peak current for each six-tube rectifier is 4167 amp. At the start of the pulse the output voltage of each rectifier is 4500 v direct current, and at the peak load the d-c voltage is 3000 v. Pumped ignitrons meet these requirements more satisfactorily than sealed ignitrons on these applications because the tubes are more rugged, the ratio of peak current to average current is higher, and they do not require replacement.

The grid circuit of the firing thyratron is the major control circuit. On this grid circuit, one peaking transformer is phased for rectifier operation and another for inverter operation; and by changing the bias value either the rectifier or the inverter firing pulses can be made effective. When proper

phase relationship releases the thyratron for firing, a capacitor is discharged through an insulating transformer to fire the ignitor.

The excitation circuit allows one half of the converters (ignitron units that operate as both rectifiers and inverters) in series to change from rectifier to inverter operation at one time, and, after a given time interval, allows the other half of the converters to change. A small commutator on the motor-generator shaft governs the rectifier-to-inverter change by removing the positive bias on the grids of the firing thyratrons. Proper timing minimizes any torsional vibrations in the motor-generator shaft.

The rectifying portion of the current pulse is the most critical because the particles are accelerated during that period. The d-c voltage magnitude and harmonics must be held to definite limits to prevent losing the protons at the start of the pulse. Voltage regulation is held to 0.5 per cent by

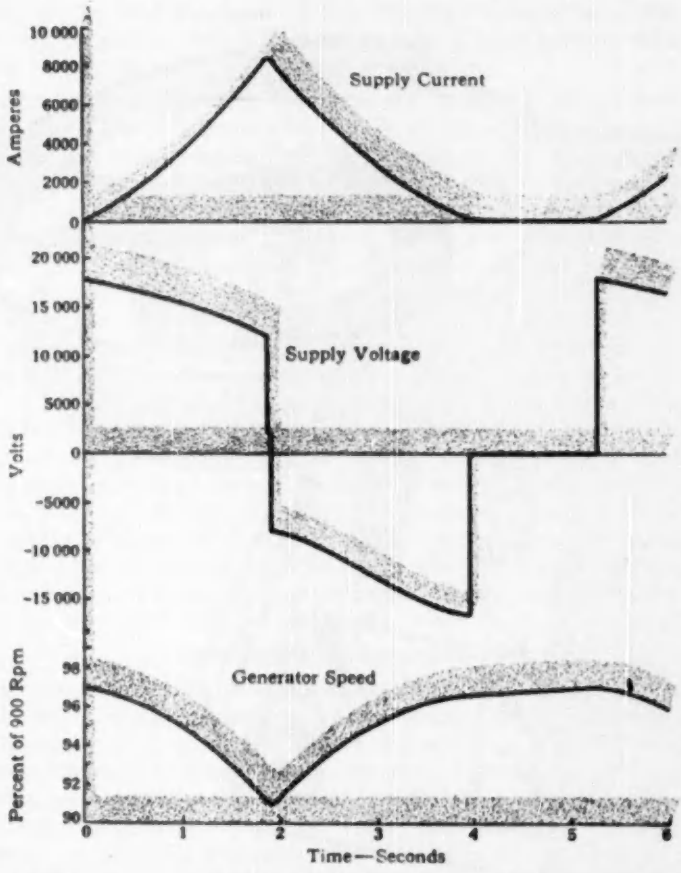

Fig. 2 The current curve shows the variation in amperage that generates the desired inductance in the main magnets. The voltage curve indicates the change in d-c voltage through the ignitron units. The notch in this curve is caused by the shifting of each ignitron half-section from rectifier to inverter operation. The speed curve shows the small drop in speed of the flywheel m-g sets

electronic regulators and electronic exciters that control the field of the main generator. As the magnitude of the d-c harmonics would otherwise be increased, no delay in rectifier firing is used; a 12-phase output voltage ripple is satisfactory.

The normal d-c voltage regulation of the motor-generator set with rectifier gives, basically, the desired characteristics. When the rectifier load increases, the voltage regulator does not attempt to hold a constant voltage as it is current compensated to hold the correct voltage for a constant flux in the generators. Because of the machine reactance, the d-c voltage drops almost the desired amount, and only a small change in the field is required to give the desired regulation.

The change from rectifier to inverter operation is a critical step, and the power circuits must be specially designed to operate correctly. When the firing direction is changed, each conducting tube must continue firing for

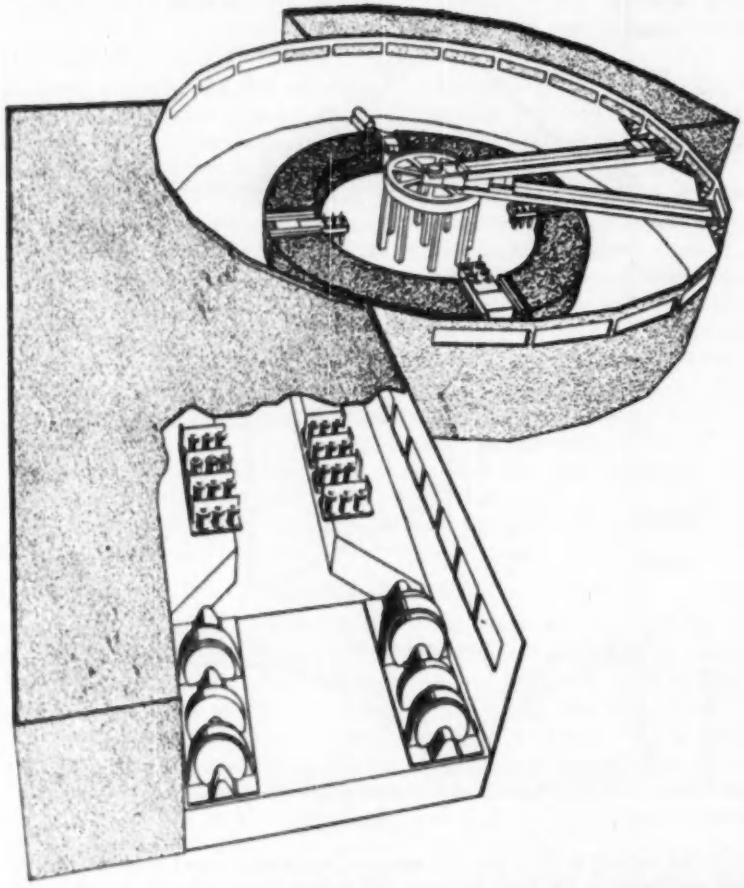

Fig. 3 This sketch of the bevatron installation at the University of California Radiation Laboratory at Berkeley indicates the general layout of the components of the most powerful atom-smasher

about double the normal angle. The voltage on each interphase transformer increases severalfold because the difference in phase position of the windings in the paralleled wyes of the two generators causes a larger difference in voltage between the two rectifier groups. The interphase exciting current under this condition must be low to prevent an unbalance that would cause inverter faults.

At the peak load, inverter firing is considerably advanced to permit commutation with a large margin angle. The magnitude of the d-c voltage is not critical during the inverter portion of the pulse. The inverter counter-voltage should be as high as possible to bring the current to zero in a minimum time and thus reduce the current loading on the equipment.

As current decreases, the ignition delay angle is increased to hold the margin angle approximately constant. Both this ignition change and the increase of the machine voltage with reduced load causes the d-c voltage to increase as the load decreases. When the load becomes zero the ignition angle must be greater than 150 deg to prevent a small positive voltage from causing current pulses in the magnet windings.

The problem of protecting the equipment in case of an ignitron fault or system short circuit is serious because it is not possible to interrupt load current in the tremendously inductive circuit of the large magnet. The peak stored energy of the magnet is about 80 million watt-seconds, therefore it is always desirable to invert the current to zero before the operation of the equipment is stopped. However, when a serious fault occurs it is necessary to stop immediately. The ignitors on all ignitrons are blocked so they do not fire and the tubes attempt to quench the arc of the fault current. If this fails to correct the fault, the main magnet is short circuited and the generator excitation is removed. The magnet current must decay according to the RL characteristics before control can be reclosed.

In the rectifier period of the pulse, an arc-back requires an arc suppression that causes disturbances in the output d-c voltage, but this lasts for only a portion of one pulse. Arc-troughs (passage of current when tube is supposedly nonconducting) during the inverter period can be corrected in one cycle without any change in excitation, because the magnet current does not increase. Unless the unbalance between groups becomes too great, the current in each wye should be commutated when the correct phase comes up the second time. If the fault is not corrected the back-up protection of short circuiting the magnet will go into effect.

FLYWHEEL-MOTOR-GENERATOR SETS

The generators were designed especially for direct connection to the rectifier tubes, which eliminates the reactive drop of the transformers. The elimination of the transformer caused the extra complication of generator windings having four wyes brought out for a 12-phase rectifier connection. A special winding, adequate for carrying the d-c component and arranged to minimize adverse effects on the rotor, was developed. It also gives a minimum commutating reactance that limits the voltage drop of the generator at the peak load. The resulting high-fault currents necessitated extra bracing for the end windings.

The m-g sets have eight-pole generators and an eight-pole wound-rotor motor running just below 900 rpm at 60 cycles. The speed was chosen as high as practical to give a minimum reactance for suitable regulation.

The inertia characteristics of the flywheel allow about a six-percent speed drop with a corresponding reduction in voltage. It might appear that a smaller flywheel would be more economical, but with a limit to the overall voltage drop a wider tolerance in speed requirements would have demanded a major reduction in reactance and an increase in generator size. Whereas the peak power input to the magnet is 100,000 kw, the average power input to the generators does not exceed 3600 hp on each of the two motors. To minimize the voltage dip, the pulsation in kva is limited to 3000. To meet these limitations the wound-rotor motors are provided with several values of secondary resistance. Then the secondary resistance and the resulting torque-slip characteristics are changed by contactors that open and close in a certain sequence as the motors slow down and accelerate.

The experience obtained from these units in the next few years will give valuable engineering data on the performance of high-voltage rectifiers and large flywheel-motor-generator sets. Thus, in providing an instrument for advanced research, advances in engineering experience are also obtained.

The Physics of The H-Bomb

IN THE ARTICLE discussing the theoretical aspects of the hydrogen bomb in the March-April issue we described the various combinations in which the three isotopes of hydrogen could be put together to form molecules. Also, we indicated how the components of these molecules could enter into nuclear reactions. These newly discivered isotopes of hydrogen materially affect the chances of achieving a thermo-nuclear reaction involving hydrogen compounds.

As pointed out by Louis Ridenour in an article in the March issue of the Scientific American, a few years ago the reaction that would have been chosen as the most promising for a hydrogen bomb was the fusion of two atoms of deuterium. This results in the formation of helium 3 with the emission of a neutron and the release of about four million electron volts of energy. Here is the equation for this reaction:

$$ {}_1He^2 + {}_1He^2 \rightarrow {}_1He^3 + {}_0n^1 + 4 \text{ Mev} $$

Gamow has calculated the thermo-nuclear energy from this reaction. As he explains it, if the reaction took place at a temperature of something over one million degrees, a small charge of deuterium could be used as an explosive with tremendous destructive power.

In view of the recently discovered isotope, H^3 we know that today a more effective reaction can be obtained. Hydrogen 3 the long-lived isotope known as tritium not only reacts faster than deuterium at low temperatures, but also liberates more energy when it does so.

A fusion reaction of tritium with deuterium produces helium 4, with the emission of a neutron. Its energy yield is 17.6 Mev, approximately the same as that evolved from the combination of four protons into a helium nucleus as described in the article in the March-April issue.[1]

Tritium can also fuse with tritium, yielding helium 4, two neutrons and 11.4 million electron volts of energy. As pointed out by Dr. Ridenour,

[1]Theoretical Aspects of The Hydrogen Bomb. By Andrew W. Kramer. ATOMICS March-April 1950. p. 4.

the cross section for this reaction is not available in the published literature, but it is probably very large. The equations expressing these two reactions are as follows:

$$_1H^3 + {}_1H^2 \rightarrow {}_2He^4 + {}_0n^1 + 17.6 \text{ Mev}$$

$$_1H^3 + {}_1H^3 \rightarrow {}_2He^4 + 2\ {}_0n^1 + 11.4 \text{ Mev}$$

As explained in the article in the March-April issue, tritium has not only become available by bombarding lithium 6 with neutrons in a nuclear reactor but ponderable amounts of tritium have been and are being made by the Atomic Energy Commission.

The designer of a hydrogen bomb would start with a fission bomb of uranium or plutonium, the explosion of which would produce the high

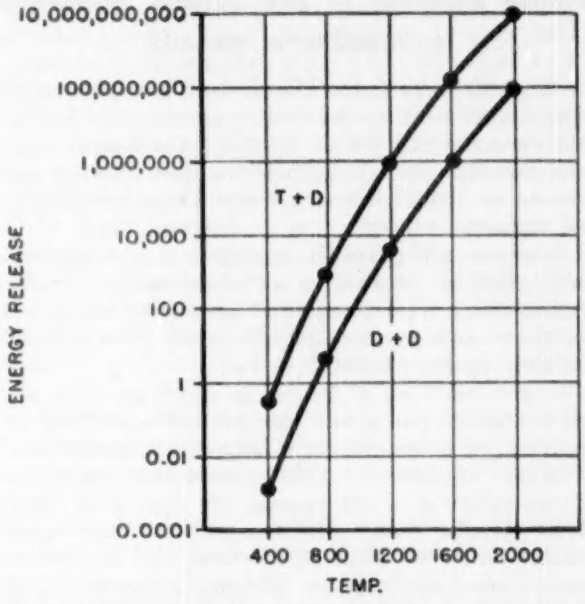

Chart showing the energy released by the fusion of deuterium with deuterium (bottom curve) and tritium with deuterium (top curve) plotted against temperature. The vertical coordinate is energy in calories per second per gram. The horizontal coordinate is thousands of degrees Centigrade. The curve is for density one (one gram in one cubic centimeter).

ignition temperature required for the thermo-nuclear fussion reaction. Tc the fission bomb he would add a certain mixture of deuterium and tritium, or perhaps tritium alone, to fuel the fusion process. The final energy release of the bomb would be determined by the amount of deuterium or tritium added.

In the popular discussions of the H-bomb it has been referred to as being a thousand times more devastating than the uranium bomb but, of course, this has little real significance. Given enough deuterium or tritium, an H-bomb of any size conceivable could be built. With the H-bomb, the limitation of *critical size* does not exist. Once ignition took place the energy release thereafter would depend only upon the amount of fuel provided for the fusion reaction.

Nuclear Power Engineering

Part X. More about neutron physics . . . Fast neutron reactions . . . Bothe and Becker's experiments and their subsequent interpretation . . . Chadwick's investigations and his discovery of the neutron . . . Methods of producing neutrons . . . Measurement of the energies of fast neutrons . . . Cloud chamber method of measuring energy of fast neutrons, its advantages and limitations . . . Photographic plate technique . . . Use of ionization chambers in fast neutron measurement.

By ANDREW W. KRAMER

IN PART IX of this series in the March-April issue we considered briefly the reasons why slow neutrons were of importance in nuclear reactions. The fact, for example, that the de Broglie wave length of a neutron is *inversely* proportional to its velocity makes a slow neutron appear to have a larger cross section than a fast one, hence a slow neutron has a greater probability of striking a nucleus.

Neutrons, however, are generally produced as fast neutrons and it is only by slowing them up by collision with light nuclei that we can obtain certain desired reactions. It is therefore of importance to study the reactions in which fast neutrons are produced. There are three principle reactions in which fast neutrons are produced.

The first of these reactions is the one in which an alpha particle enters a nucleus and a neutron is emitted. This reaction was the first reaction in which the existence of neutrons was indicated. In certain experiments by Bothe and Becker[1] reported in 1930 it was observed that some light elements emitted radiation of the gamma ray type when they were bombarded by alpha particles from a polonium source. The element beryllium gave a particularly marked effect of this kind and later observations by Bothe, Mmme. Curie-Joliot[2] and by Webster[3] showed that the radiation excited in beryllium possessed a penetrating power distinctly greater than that of any gamma radiation yet found from the radioactive elements. In Webster's experiments the intensity of radiation was measured both by means of the Geiger-Muller tube counter and in a high-pressure ionization chamber. From absorption measurements of these radiations and subsequent corrections for experimental conditions and estimates of the effect of scattering in the case of such penetrating radiation, Webster, concluded that the radiation had a quantum energy of about 7×10^6 electron volts. Similarly, he found that radiation from boron bombarded by alpha particles from beryllium, had quantum energies of around 10×10^6 electron volts. These conclusions agreed quite well with the supposition that the radiations arose by the capture of the alpha particle into the beryllium (or boron) nucleus and the emission of the surplus energy as a quantum of radiation.

The radiations showed certain peculiarities, however, and this caused

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[1] Z. Physik, Vol. 66, p 289.

[2] I. Curie, C. R. Acad. Sci. Paris, Vol. 193, p 1412 (1931)

[3] Proc. Roy. Soc. A, Vol. 136, p 428 (1932)

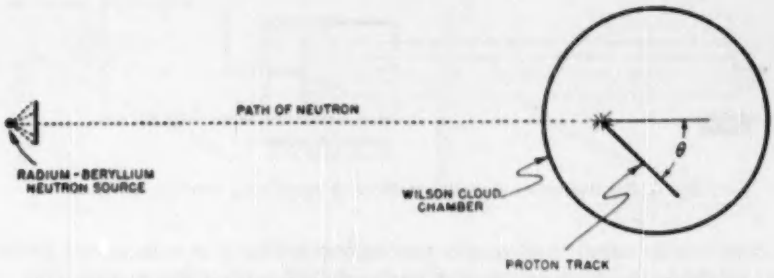
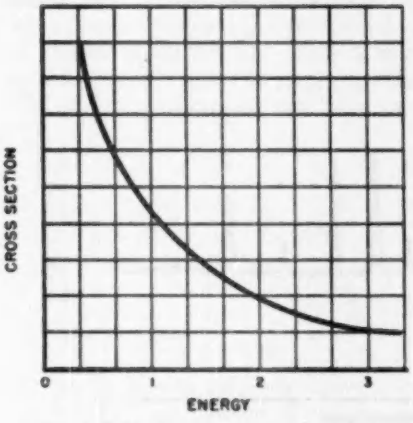


Fig. 1 Showing the Wilson cloud chamber of measuring fast neutron energies

Chadwick to study the phenomenon in greater detail. In the meantime Mme. Curie-Joliot and M. Joliot made the very striking observation that these radiations from beryllium and from boron were able to eject protons with considerable velocities from matter containing hydrogen. In their experiments the radiation from beryllium was passed through a thin window into an ionization chamber containing air at room pressure. Whe paraffin wax, or other matter containing hydrogen, was placed in front of the window, the ionization in the vessel was increased, in some cases as much as doubled. The effect appeared to be due to the ejection of protons, and from further experiment they showed that the protons had ranges in air up to about 26 cm, corresponding to a velocity of nearly 2×10^9 cm per sec. They suggested that energy was transferred from the beryllium radiation by a process similar to the Compton effect with electrons, and they estimated that the beryllium radiation had a quantum energy of about 50×10^6 electron volts.

It was, however, very difficult to account for the production of a quantum of 50×10^6 electron volts from the interaction of a beryllium nucleus and an alpha particle of kinetic energy of 5×10^6 electron volts, and their were other difficulties.

It was the failure of existing theories to explain the action that led Chadwick, around 1931, to suppose that the radiation consisted of particles



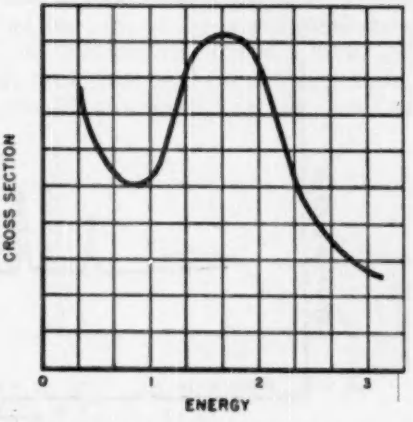


Fig. 2 (left) Curve showing the relation between cross section and neutron energy

Fig. 3 (right) This curve shows the effect of resonance upon cross section

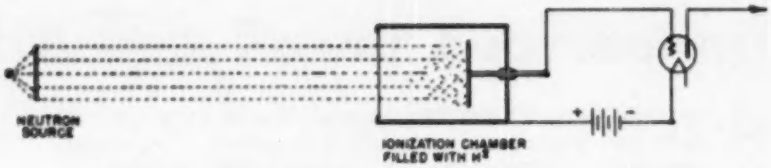


Fig. 4 The ionization chamber method of measuring neutron energies

of mass nearly equal to that of a proton but with no net charge—a particle that might be called a neutron. Chadwick had made some experiments and a short statement of his observations was published in *Nature* in 1932. This, then, is how the existence of the neutron became known. And this is why the alpha particle-neutron reaction is of such historical interest.

A second type of reaction in which neutrons are produced is the reaction in which a deuteron impinges on the nucleus and a neutron is emitted. The symbol for this reaction is (d,n). Two reactions of this type have become of great practical importance. One is the Be (d,n) reaction in which the beryllium is the bombarded nucleus and which gives a copious source of neutrons. Another is the D (d,n) reaction in which the deuteron hits a stationary deuteron in the target. In this reaction monoenergetic neutrons can be produced, that is, all the neutrons will have the same energy, the amount of energy depending upon the energy of the impinging deuteron. Neutrons between 2 Mev and 7 Mev may be produced in this manner if the incident deuterons have an energy of 3.5 Mev.

The third important source of neutrons is the (p,n) reaction and in particular the Lithium (p,n) reaction. In this reaction a lithium nucleus is bombarded by protons and neutrons emerge, leaving the compound beryllium nucleus behind. This reaction is endoenergetic, that is, the protons must have a certain minimum energy in order that the reaction should proceed at all. Monoenergetic neutrons between 10,000 electron volts and 2 Mev may be produced by this reaction for the similar range of incident particle energies, that is, up to 3.5 Mev.

The Lithium (p,n) reaction may be written in somewhat more detail as follows:

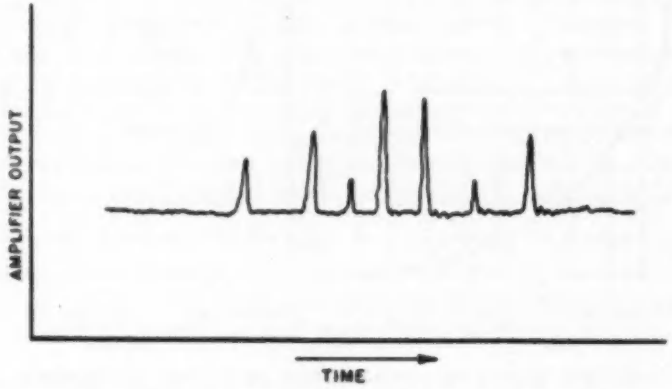
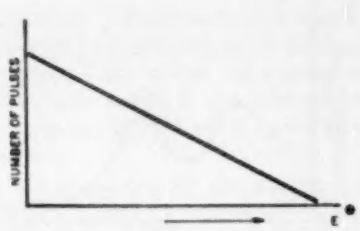


Fig. 5 The height of the pulses indicate the energy of the neutrons



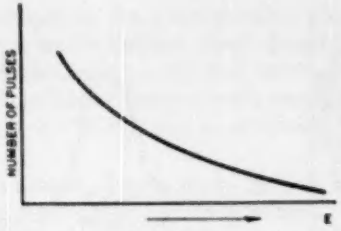


Fig 6A (left) Number of pulses which have more energy than a given value E plotted against amplifier output pulse energy with monoenergetic neutrons

Fig. 6B (right) Curve similar to that in Fig. 6A but for distribution of neutrons with various energies

$$_3Li^7 + {}_1H^1 \rightarrow n^1 + {}_4Be^7 + Q$$

where the energy of reaction Q is a negative quantity.

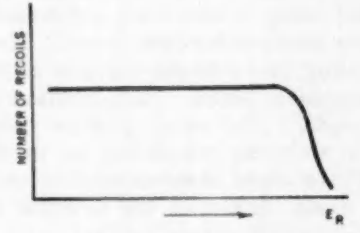
Of course, as previously explained, if the kinetic energy of the impinging proton in the lithium hydrogen bombardment process is below 2 Mev, an entirely different reaction may take place, a reaction in which the compound beryllium nucleus formed splits up into two helium nuclei, as shown by the following equation:

$$_3Li^7 + {}_1H^1 \rightarrow ({}_4Be^8) \rightarrow {}_2He^4 + {}_2He^4$$

Thus, it will be seen that the production of neutrons by bombardment is dependent upon a number of factors, including the energy of the impinging particle.

MEASURING THE ENERGY OF FAST NEUTRONS

The first method of measuring the energy of fast neutrons was by means of the Wilson cloud chamber. The arrangement used is shown in Fig. 1. At the left is a source of neutrons. This may be a radium-beryllium source as already described. At the right is a Wilson cloud chamber. This chamber is filled with a gas of small atomic weight such as hydrogen or helium. The path of the neutron is shown by the dotted line. Upon entering the cloud chamber it collides with a nucleus of hydrogen or helium and the solid line in the cloud chamber indicated the path of the recoiling particle. If this track makes the angle θ with the continuation of the path of the neutron, then, from this angle, and from the energy of the recoiling particle, the original energy of the neutron may be calculated. If the recoiling



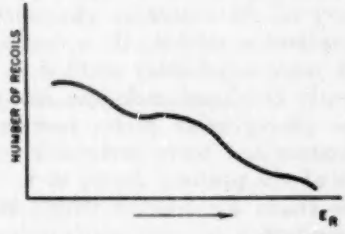


Fig. 7A (left) By differentiating curve in 6A we obtain this curve which gives the number of recoiling particles of a given energy

Fig. 7B (right) Curve similar to that in 7A but for distribution of neutrons with varying energies

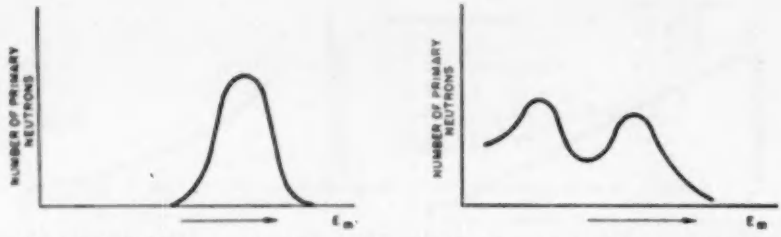


Fig. 8A and 8B Curves showing number of primary neutrons for monoenergetic neutrons and neutrons of varying energies respectively

particle happens to be a proton then the energy of the neutron is given by the equation:

$$E_r = E_n \cos^2 \theta$$

Where E_r is the energy of the recoiling particle and E_n is the original energy of the neutron. In these experiments, it is usual to count only the tracks which go in the forward direction and which make only a small angle θ (smaller than, say, 10 deg) with the direction of the incident neutron. Then the factor $\cos^2 \theta$ in the formula may be neglected and the energy of the recoiling proton is equal to the energy of the incident neutron.

One danger of this procedure is that the neutron might have been scattered in the wall of the cloud chamber and while the proton seems to go forward, it actually does not lie in the continuation of the path of the walls of the neutron which has hit it. Another difficulty is that the tracks of the recoiling particle are rather long and they may not end in the chamber. Naturally, the energy of such recoils cannot be measured.

Cloud chamber measurements of neutron energy are subject to further difficulty because a previous knowledge of the dependance of the collision cross section on the energy of the incident neutron is required. A typical dependence of this cross section on the neutron energy is shown in Fig 2. As will be noted, the cross section decreases as the energy increases. And, as pointed out in previous chapters the cross section is further complicated in the case of certain nuclei by the phenomena of resonance. In the case of helium for example, the cross section varies with energy as shown in Fig. 3. It has a resonance between 1 and 2 Mev.

Thus, in Wilson cloud chamber experiments where helium is used in the chamber, resonance will give rise to a greater number of tracks if the incident neutron has an energy between 1 and 2 Mev. Previous to the discovery of the resonance phenomena these many tracks were erroneously interpreted as showing the presence of many neutrons between 1 and 2 Mev.

A more satisfactory method of measuring fast neutron energies is the recently developed technique using photographic plates. The emulsion of these photographic plates contain hydrogen. The recoil protons cause ionization and leave devlopable grains in the wake which line up in the path of the proton. Again as in the Wilson cloud chamber method only those tracks are counted which make a small angle with the direction of the neutron.

This photographic technique has the following advantages as compared to the cloud chamber method. To begin with, the stopping power of the photographic emulsion is greater, the length of the tracks being only a few thousandths of an inch long; consequently, the danger of the track leaving

the emulsion before ending is smaller. Second, in the photographic plate there need be much less material than there is in the Wilson cloud chamber; consequently the danger of a scattered neutron causing a recoil is decreased. A third advantage is that the photographic plate is continuously sensitive while the sensitivity of a cloud chamber is restricted to the moments of expansion.

A disadvantage of the photographic technique, however, is that it becomes inaccurate in counting slower neutrons. The recoils produced by such neutrons make few grains and since the number of grains produced is used in determining the neutron energy, fluctuations in the number of grains make such energy determinations difficult. The photographic method must be calibrated by using a reaction of known energy.

Ionization chambers can also be used to determine the energies of neutrons. This method is less straightforward but somewhat more trustworthy. As shown in the arrangement in Fig. 5, neutrons enter the ionization chamber through a thin *window*. The chamber is filled with hydrogen. A negatively charged electrode in the chamber is connected to the input of a vacuum tube amplifier. When a neutron enters the chamber it produces ions by collision with the hydrogen atoms and since these ions (protons) are positively charged they are attracted to the negative electrode where they give up their charge. This produces a pulse of current in the grid circuit of the first amplyfying tube and this pulse is amplified so as to be able to actuate a recording, indicating or integrating instrument. Figure 5 is a graph of these amplified pulses, each of which corresponds to the energy of one recoiling particle. The height of the pulses is a measure of the energy of the particle and this, of course, is dependent upon the angle which the recoiling particle makes with the neutron. This assumes that the neutrons are monoenergetic, that is, they all have the same energy.

If we plot the number of pulses which have more energy than a given value E against the amplifier output height a curve such as that shown in Fig. 6A is obtained. If, however, instead of a beam of monoenergetic neutrons, a distribution of neutrons with varying energies impinges on the ionization chamber, a curve such as that shown in Fig. 6B will result.

By differentiating each of these curves (Figs. 6A and 6B) the number of recoiling particles of a given energy is obtained. The corresponding curves resulting from such differentiation are shown in Figs. 7A and 7B.

With hydrogen in the ionization chamber, a second differentiation gives

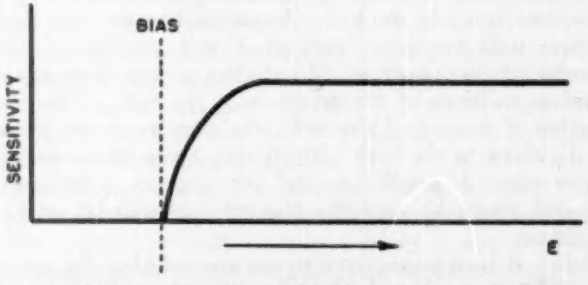


Fig. 9 Sensitivity curve of an amplifier biased to cut off all pulses less than those of a certain energy

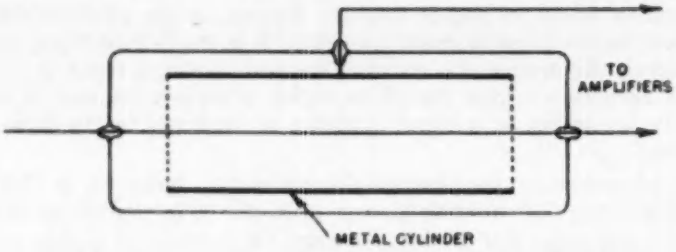


Fig. 10 Diagram of a proportional type of ionization chamber employing gas amplification

the number of primary neutrons as plotted against their energy, E_o. Again, the corresponding curves are shown in Figs. 8A and 8B.

Several other schemes are possible. Instead of recording pulses of various heights, an amplifier could be used with a bias such as to cut out all pulses less than a certain energy. As shown in the sensitivity curve in Fig. 9, below the bias the amplifier-detector will not respond at all. At higher energies the sensitivity rises to a plateau as shown and after that, will decrease.

USE OF PROPORTIONAL COUNTERS

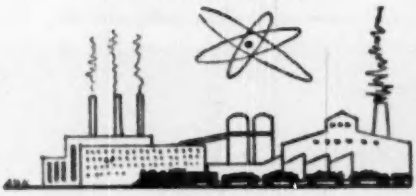
With ionization chambers of the type shown in Fig. 4, it is necessary that the pulses to be counted have energies of at least 100 kv; below that, they are insensitive. This limitation may be overcome by the use of a different type of counter, the proportional counter shown in Fig. 10. This type of counter makes use of what is known as gas amplification. Like the first counter described, this chamber is filled with hydrogen gas but instead of a plate electrode it has a collecting wire which is stretched through the center of a conducting cylinder. These form opposite electrodes, hence there is a strong electric field surrounding the central wire. In this field electrons are accelerated toward the wire causing further ionization and in this way greater pulses result. With these proportional counters pulses as small as 10 kv may be detected.

The measurement of both the energy and the number of fast neutrons is rather difficult regardless of the particular method used. In a method used by Fermi and Amaldi, the fast neutrons were slowed down in a water bath of sufficiently large volume surrounding the neutron source on all sides. After being slowed down the neutrons were detected by rhodium or indium foils distributed in the bath. From the known cross sections of the nuclei in these foils for slow neutrons it was possible to determine the original number of fast neutrons. To do this it was necessary to integrate over the various positions of the detectors in the bath. This last operation may be avoided if instead of the foils, the slow neutrons are detected by manganese dissolved in the bath. By stirring the solution and by taking a sample afterwards it is possible to find the integral of neutron absorption in the bath and from this quantity the original number of fast neutrons can be calculated.

In conclusion, it is of importance to understand that the principal reason why it is so difficult to measure the energies and count the number of fast neutrons is because the cross section of fast neutrons is much smaller than

that of slow neutrons. Since fast neutron reactions enter into the processes operating in nuclear reactors as well as slow neutron reactions, it becomes necessary to investigate the processes that occur when fast neutrons impinge on nuclei. The transmutation of U-238 into plutonium for example is brought about by fast neutrons and this reaction, of course, is of the greatest importance in the design of a nuclear reactor whether its purpose be the generation of power or the production of plutonium.

(To be continued)



Atomic Fissions

News From The Atomic World

Atomic Power Program Deferred at Knolls by Production Speed-Up

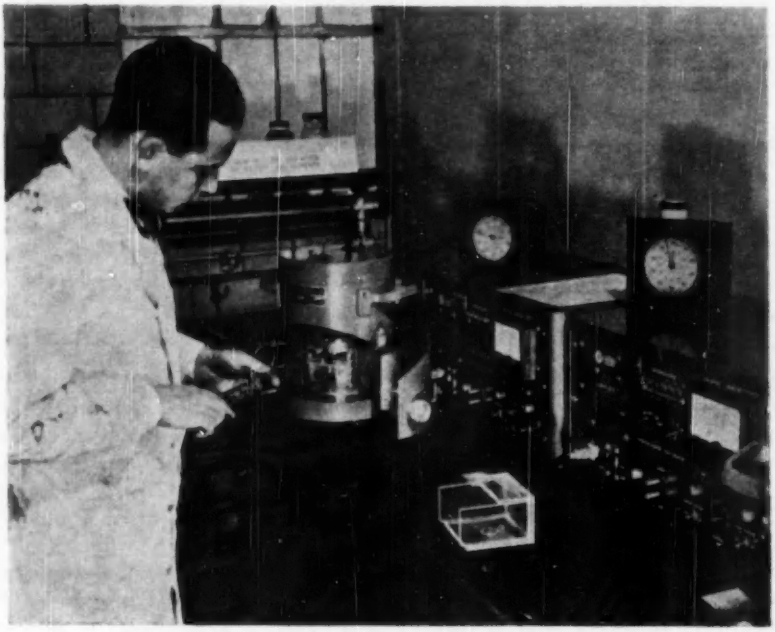
Extensive revision of the research program of the Knolls Atomic Power Laboratory to provide for maximum participation of the Laboratory technical staff in an expanded atomic energy production program at the Hanford Works, and to speed-up design and development of a land-based prototype for a ship propulsion reactor has been authorized by the AEC. While no official explanation is given this change in plans no doubt has something to do with the development of the hydrogen bomb.

The Commission's authorization follows recommendations of the General Electric Co., whose Research Laboratory operates the Knolls Atomic Power Laboratory, as to the best method of using KAPL manpower in speeding up the overall atomic energy program, in accordance with program goals set by the Commission.

The reorientation of the KAPL research followed a Commission action deferring the start of construction of the West Milton intermediate power-breeder reactor project, upon whose design the Knolls Atomic Power Laboratory has worked along with preliminary design of the ship reactor. It is estimated that from two-thirds to three-fourths of the research and development work already done on the intermediate power-breeder reactor will find use in the accelerated ship propulsion reactor project.

The Ship Intermediate Reactor (SIR) is a second and simultaneous attack by industrial contractors of the Commission on the problem of applying atomic energy to naval ship propulsion. The Argonne National Laboratory and the Westinghouse Electric Corp. are developing designs for a land-based prototype of a Ship Thermal Reactor (STR) suitable for naval ship propulsion. Although both reactors will be designed to meet similar Navy performance specifications they will be separate projects, involving different approaches and therefore different technical and engineering problems.

The plans for the SIR will call for a single-purpose machine designed specifically to produce large amounts of heat to be used for generating power. This is the difference between the SIR and the original West Milton power-breeder reactor. The latter was designed both for power production and for breeding reactor fuel. The two naval reactors will contribute considerable amounts of data and operating experience which should prove invaluable in the development of future reactors for the production of power for commercial use.



Atomic Waste Research at Engineering College

Werner N. Grune, research assistant, New York University College of Engineering, removes a radioactive specimen from its lead container with a set of tongs in Carpenter Sanitary Engineering Laboratory at University Heights. The College of Engineering, through its Research Division, is actively engaged in a project sponsored by the Atomic Energy Commission which seeks to find solutions for problems concerned with atomic energy wastes.

Element 98, Californium, Identified by U. of Calif. Scientists

The discovery of element 98, another synthetic unit of matter which does not exist in nature and has never before been observed on earth, was reported recently by University of California scientists working under contract with the AEC.

Element 98, named Californium after the University and the state, is the heaviest atom ever known, standing six steps up the periodic table from Uranium, the most massive atom in nature. It was made by bombarding Curium, element 96 (at weight 242), another of man's synthetic products,

with 35 million electron volt alpha particles, the nuclei of Helium atoms, fired from the University's 60-inch Crocker cyclotron.

Not enough of element 98 was made in the bombardment to be visible; indeed, the weight of the curium target was only a few millionths of a gram. The new element is so intensely radioactive that half of a given quantity loses its radioactivity, thereby transforming itself into a lighter element, in a matter of 45 minutes (the period of its half life). It decays by emitting alpha particles.

The new element has no practical place in atomic energy either for atomic bombs or power. It is of fundamental importance, however, in expanding man's understanding of matter.

Last January the same group of scientists reported the discovery of element 97, named Berkelium in honor of the city of Berkeley. Dr. Glenn Seaborg, has led the groups of scientists responsible for the discovery of all the synthetic elements heavier than Uranium, excepting only element 93, Neptunium.

Strongest Electron Accelerator to be Made from Model of Proton Accelerator

A quarter-scale pilot model of what is expected to be the world's most powerful machine for accelerating protons will be converted into the world's strongest electron accelerator under the terms of a research agreement involving the California Institute of Technology, the Radiation Laboratory of the University of California, and the AEC.[1]

The quarter-scale model of the proton machine, whose full-scale counterpart will be called the bevatron, was designed, built and successfully operated by scientists at the Radiation Laboratory, Berkeley. It was built to test new design principles for the full-scale bevatron which is now under construction. The large machine is so named because it will operate at energies of more than a billion electron-volts (Bev) with probable maximum energy of 5 to 7 billion electron volts.

The pilot model has been dismantled and will be rebuilt at C.I.T., Pasadena, to provide one billion-volt electrons and X-rays for nuclear physics studies, particularly in the field of meson physics.

For some time physical scientists at C.I.T. have been working on plans for a high-voltage electron accelerator with the support of the Commission and the Office of Naval Research. The plan to use the model bevatron equipment from Berkeley and to install it in a building immediately available will result in operation of this machine perhaps a year sooner than could normally be expected in such a project.

The full-scale bevatron will product protons having energies from 2 to 3 times greater than any other being designed. To solve the many new problems posed by this complex machine, the Commission authorized the Radiation Laboratory to use $350,000 of its funds for the construction of a quarter-scale working model of the big machine.

This working model was designed and built in a period of 10 months. The information obtained from its operation is expected to save the cost

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[1]See Power For Atomic Accelerators, page 5.

of the model out of the final construction costs of the big machine. For example, designers may be able to reduce by some 600 tons the quantity of steel originally thought to be required for the enormous magnets of the bevatron. It will also make it possible to begin operation of the machine at 3.5 billion electron-volts instead of the 1.4 billion electron-volts originally planned. Information learned from the model is expected to cut many months off the "shakedown time" of the full-size instrument, and has erased any doubt that such an accelerator will operate as planned.

According to present plans as few changes as possible will be made in the Berkeley model in order to adapt it to the C.I.T. requirements. The speeding electrons will travel around a race-track shaped path having a radius of 11.5 feet. The accelerating impulse will be provided by a radio frequency system, and the negatively charged electrons will be kept on the course by means of large electro-magnets.

At top speed the electrons will be moving at velocities only one ten-millionth of one per cent less than the speed of light, the theoretical but unattainable top velocity for any material particle.

In smaller electron accelerating machines, such as betatrons and synchrotrons, the electron speeds also approach within one per cent or less of the speed of light. The velocity imparted to electrons with the larger machine is not substantially increased. Instead, the large difference in energies between electrons accelerated in the smaller machines and the large one is represnted almost entirely by increased mass in accordance with the Einstein relativity theory.

At rest the tiny negatively charged electrons weigh only 1/1840 as much as positively charged protons. When accelerated to a billion electron-volts, however, the mass increases to more than that of the proton. This increase in mass plus the fact that the particle carries a negative charge make billion-volt electrons important in nuclear research.

The electrons will issue from the accelerator in pulses, initially at the rate of about 12 pulses per minute. Each pulse will contain about 10 billion particles.

New Atomic Energy Air Filter May Have Industrial Use

A new inexpensive paper-like filter material designed for filtering fine radioactive particles from contaminated gaseous wastes has been developed for the Atomic Energy Commission by Arthur D. Little, Inc., Cambridge, Mass. The development may have general commercial or industrial use, for instance in filtering the smokestack gases which now cause fumes or smog.

The new material contains treated paper-making fibers in combination with very finely divided mineral asbestos fibers. The material is made in soft, flexible sheets which can be pleated and formed into shapes to fit filtering units of large capacity.

AEC facilities using cooling or ventilating air which might become contaminated with radioactive particles take extreme care to elminate such particles before the air is discharged into the atmosphere. Air filters developed and used by the Chemical Warfare Service for protection against gas warfare have proved satisfactory, and for some years the Army has been supplying AEC with filter units. With the expansion of the atomic energy program, however, the demand for filters has grown rapidly. In

order to develop alternate sources of supply and possibly to reduce filter costs, the AEC initiated a program for filter research and development.

The material was developed by Arthur D. Little, Inc., under contract with AEC. The paper can be made on relatively slow Fourdrinier machines of a type found in a large number of paper mills fabricating soft saturating papers. Thus, the atomic energy program can be assured a diversified source of supply.

New G-E Portable Radiation Detector

A new portable radiation detector, the long-probe Gamma Survey Meter, which enables the operator to measure radioactivity from a distance has been announced by the Special Products Division of the General Electric Co.

The new instrument can be used for monitoring areas in which radioactivity is suspected or for other types of radiation metering.

A detector located at the tip of a four-foot-long probe converts radioactive emanations into electrical energy. This detector consists of an electronic tube and a phosphor, a material which gives off light in the presence of radioactivity. Light from the phosphor acts upon the electronic tube, which converts the light energy into electrical energy and amplifies its magnitude.

Long-probe radiation detector being used to monitor a laboratory safe containing radioactive isotopes, which are enclosed in a heavy metal cannister and surrounded by lead bars to prevent possible radiation.

At the other end of the instrument, a dial is activated by amplified energy from the tube. It registers the amount of radiation exciting the phosphor four feet away. The detector is powered by 1000 v induced from low-voltage batteries, which are enclosed in a box that can be carried over the operator's shoulder.

New Atomic Research Project for San Francisco Bay Area

.... The U. S. Atomic Energy Commission has announced that a new classified research project is being undertaken in the San Francisco Bay area. The project involves the construction of a particle accelerator which will be used to pursue a classified research program for the AEC. The project is expected to cost about $7,000,000.

The program will be undertaken by the California Research and Development Company in cooperation with the Radiation Laboratory of the University of California. The new project will be undertaken at the Livermore Naval Air Station through the cooperation of the Navy Department, which has agreed to work with the Commission in obtaining a transfer of the property. It is expected that the preparation of the Naval Air Station site for the new project will involve the modification of some of the existing buildings as well as some new construction. Work at the site is scheduled to begin within the next few weeks.

Non-ferromagnetic Synchrotron Successful in First Tests

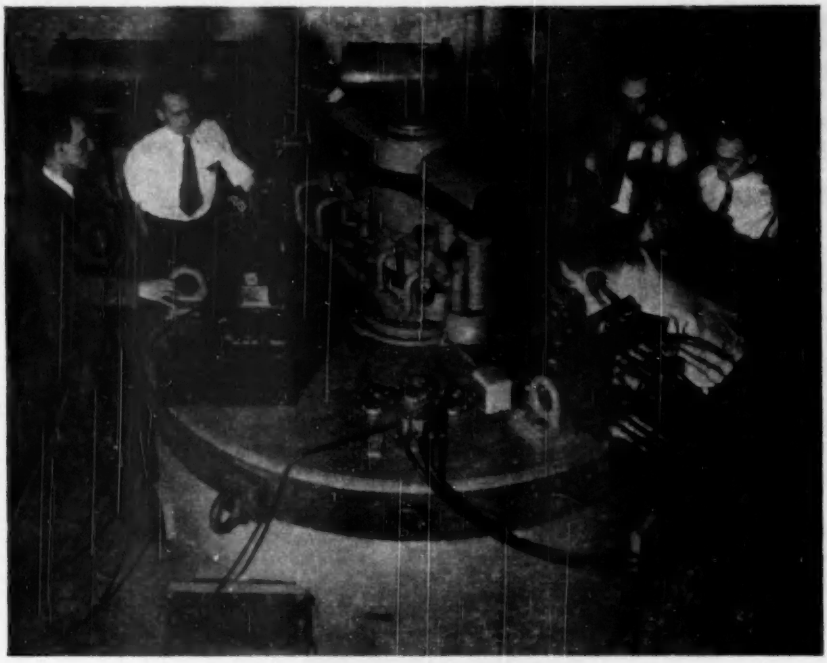
Successful operation in its first phase of a new type of atom smasher, which is ultimately expected to produce X rays of 300,000,000 volts, has been announced by Dr. C. C. Suits, director of research for the General Electric Co.

The new machine, said Dr. Suits, is known as a "non-ferromagnetic synchrotron," and is being built under the joint sponsorship of the Office of Naval Research and the G.E research Laboratory. It has been operated thus far up to about a million volts and probably it will be in operation at much higher energies before the end of the year, Dr. Suits stated. It will be used to study the effects of high-energy radiation, particularly in nuclear research.

The new particle accelerator, or atom smasher, is of a design that eliminates the huge iron-core electromagnet commonly used in such devices. The requisite powerful magnetic fields are produced solely by specially designed coils of wire. These carry heavy currents, and are contained in a steel tank from which air has been exhausted.

First erected in one of the old buildings of the G-E Research Laboratory in downtown Schenectady, the new synchrotron is now being installed in its own building at the laboratory's new quarters at the Knolls, in nearby Niskayuna. In charge of its design and construction are Dr. James L. Lawson and his associates, Drs. E. B. Gaerttner, W. B. Jones, H. R. Kratz, G. L. Ragan, H. G. Voorhies and M. L. Yeater.

A synchrotron of the same general type, designed by Dr. MacMillan and producing 300,000,000-volt radiation, is now in operation at the University of California. It has a 130-ton electromagnet. Similar machines have been constructed at Massachusetts Institute of Technology, Cornell University and other laboratories. Physicists believe that the synchrotron principle may be applied advantageously to acceleration of electrons up to perhaps a billion volts.



Non-ferromagnetic Synchrotron under test

In the non-ferromagnetic synchrotron of Dr. Lawson and his associates, according to Dr. Suits, there is a cylindrical steel tank 26 inches high and 6½ feet in diameter, with one-inch thick walls. Inside there are a group of coils for initial betatron acceleration and subsequent synchrotron operation.

There is no separate doughnut, as the entire tank is evacuated and the electrons move in the space between the inner and outer coils. During first operation the vacuum was about a hundred millionth of an atmosphere. This allows enough gas molecules to remain to cause appreciable scattering of the electrons, though it does not prevent operation. As the vacuum is improved, to a billionth of an atmosphere or better, the scattering may be decreased accordingly.

Safe Handling of Radioactive Wastes

A non-technical report on the safe handling of radioactive wastes in the atomic energy program has been issued by the Atomic Energy Commission. The report describes radioactivity and its biological effects, the types and sources of radioactive wastes in the atomic energy program, and the methods used for safe handling of wastes and protecting workers and the public from radioactive contamination. It also gives details about the extensive research program currently supported by the AEC to improve waste handling and storage methods. As better methods are devised, they are put into routine operation at atomic energy plants, often bringing about considerable savings in the cost of waste control.

For example, recent improvements in processing wastes from chemical separations plants have reduced by 20 percent the volume of liquid wastes

which must be stored. It is expected that the amount will be reduced to 50 percent in the near future, which will result in saving about a million dollars a year.

The report entitled, "Handling Radioactive Wastes in the Atomic Energy Program," may be obtained from the Superintendent of Documents, Government Printing Office, at 15 cents per copy.

Canadian Radioisotopes Available to U. S.

Procedures have been developed by the AEC in cooperation with the Department of State that will enable qualified American applicants to obtain radioisotopes under the Canadian export program announced in Ottawa. Under the procedures, applications for Canadian-produced isotopes may be made, starting today, to the Isotopes Division, U. S. Atomic Energy Commission, P. O. Box E, Oak Ridge, Tennessee. The Isotopes Division has been named the coordinating agency for the import of Canadian radioisotopes, as it is for the domestic distribution and export of U. S.-produced isotopes, and will process all applications for the Canadian materials which originate in the United States.

The U. S. Representative in Canada who will handle matters connected with the import of Canadian isotopes into the U. S. will be Mr. Curtis A. Nelson, USAEC Liaison Officer at the Atomic Energy Research Establishment, Chalk River, Ontario.

Please admit two Russian Spies . . . Its signed correctly . . . Okay, Pass on.

Recent Developments In Use of Radiocobalt

Radioactive cobalt (cobalt-60), which has been under investigation for several years as a possible substitute for radium in the treatment of cancer, is now being used experimentally for the treatment of selected types of cancer of the womb in humans at the Ohio State University School of Medicine.

To date, approximately 35 cancer patients have been treated with the material. It will require several years, however, to determine in proper perspective the relation between cobalt-60 and radium in the treatment of cancer, since the effectiveness of cancer treatments cannot be determined except over periods of from 5 to 10 years. Use of the new technique at Ohio State has been underway for only a year.

Radiocobalt is a radioisotope that can be produced in nuclear reactors. Whereas radium costs between $15,000 and $20,000 per gram, radiocobalt is available to cancer researchers at a minimal charge for handling.

New Books on Atomics

Photoelectricity and Its Application, by V. K. Zworykin and E. G. Ramberg. First Edition; 494 pages; 6 by 9¼ in.; illustrated; cloth. Published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. Price $7.50.

In 1887 when Heinrich Hertz was conducting his classical researches on electric waves which subsequently led to the development of radio in all its ramifications, he noticed another curious phenomena which, if not of equal importance to his discovery of electric waves, is at least a close second. This was the photoelectric effect. Hertz noticed that an electric spark would jump across a spark gap more easily if the gap was exposed to ultraviolet light than when the ultraviolet radiation was not present. It was a comparatively slight effect but Hertz was an extremely observant scientist and so he investigated the phenomena. Subsequently it was shown that the effect was due to the emission of electrons from metallic surfaces when they were exposed to various types of electromagnetic radiation. This photoelectric effect today not only lies at the base of our whole television industry, but it has innumerable applications in industry and in many fields of scientific research.

Because of the great importance of the photoelectric effect in modern industry and scientific research, this book by Zworykin and Ramberg is very welcome. Although this is the first edition of the book, actually it replaces a previous book entitled, "Photocells and Their Application" by Zworykin and Wilson. This present book retains the aim of its predecessor to present the reader with practical, reliable data on the properties, preparation and applications of photoelectric devices. So many developments have taken place in this field since the publication of the Zworykin-Wilson edition that the new book is about twice as large. It aims to give an integrated representation of the whole field of photoelectricity covering basic principles, methods of preparation, photocell circuits, and the various principal fields of application of photoelectric devices.

The book begins with a brief account of earlier developments in the field of photoelectricity and is followed by a discussion of light sources and the basic principles of the photoemissive effect.

The tone of the book is primarily practical. It includes circuit diagrams, graphs and other illustrations designed to allow the reader to use the material

directly. Mathematical developments are restricted to footnotes. This does not interrupt the reader's train of thought and allows the text to be followed by a person with little mathematical training.

The book contains full discussion of phototubes, photoconductive cells, barrier-layer cells, and other photoelectric devices with respect to basic mechanism, preparation, utilization and application.

Vladimir Zworykin hardly needs to be introduced to those who have any knowledge of radio and related developments. At the present time Dr. Zworykin is Director of Electronic Research and Vice President and Technical Consultant of the Radio Corporation of America. It was Dr. Zworykin while engaged in research for the Westinghouse Electric Corp. who developed the iconoscope, forerunner of all modern high-sensitivity television camera tubes. Dr. Ramberg is at present Research Physicist for the RCA Laboratories. Dr. Ramberg moved to this position from a similar one with the RCA Manufacturing Co. His undergraduate work was done at Cornell University to which he returned as Research Assistant in 1932, after having completed graduate work and receiving his Ph.D. at the University of Munich.

Electronic Instruments, edited by Ivan A. Greenwood, Jr., J. Vance Holdam, Jr., Duncan MacRae, Jr. First edition; 721 pages; 6½ by 9 in.; illustrated; cloth. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N. Y. 1948. Price $9.00.

This book is the 21st volume of the Massachusetts Institute of Technology's Radiation Laboratory Series. The tremendous research and development effort that went into the development of radar and related techniques during World War II resulted not only in hundreds of radar sets for military use but also in a great body of information and new techniques in the electronics and high-ffrequency fields. Because this basic material is of great value to science and engineering, it seemed most important to publish it as soon as security permitted. Once the Radiation Laboratory's proposals were approved and finances provided by the Office of Scientific Research and Development, Louis N. Ridenour was chosen as Editor-in-Chief to lead and direct the entire project of writing the many books involved. Altogether there will be 28 volumes in this series and, as stated before, this is the 21st volume.

As pointed out in the preface, the title of this book, Electronic Instruments, carries with it the implied adjective "some." The specific kinds of electronic instruments which are treated are electronic analogue computers, instrument servomechanisms, voltage and current regulators and pulse test equipment. Aside from the common denominator indicated by the title, these four types of equipment share claims as important adjuncts to many modern radar systems.

The book is arranged in five parts. Part I gives examples and uses and describes the step by step methods used in the design of electronic computers; Part II illustrates the potentials for new applications of servomechanisms and gives the procedures and techniques used in the design of instrument servomechanisms; Part III analyzes simple and degenerative generators; Part IV is devoted to the general subject of pulse test equipment; and Part V considers the design and construction of electronic apparatus in general. The work of many men and many different organizations, this book contains a wealth of information which can be applied in many different fields.

Any book described in this department may be purchased from the Book Department, ATOMICS, Technical Publishing Company, 53 W. Jackson Blvd., Chicago 4, Illinois

The Atomics Bookshelf

Introduction to Radiochemistry. By Gerhart Friedlander and Joseph W. Kennedy. John Wiley & Sons, Inc. $5.00

An excellent, up-to-date book describing the nature and applications of radioactivity without assuming previous knowledge of nuclear physics. It begins with a brief discussion of the historical background which is used as an introduction to the early chapters on descriptive information about atomic nuclei, nuclear reactions, and the apparatus used for the acceleration of nuclear projectiles. Later chapters discuss all aspects of nuclear phenomena.

Radioactive Tracer Techniques. By Geo. K. Schweitzer and Ira B. Whitney. D. Van Nostrand Co. $3.85

A useful manual designed to serve as a guide for laboratory work and instruction in the use of radioactive tracers. It should be of value to all who may have use for radioactive isotopes as tracers in industrial or medical applications.

The Atomic Story. By John W. Campbell. Henry Holt & Co., $3.00

By all odds the best and most interesting book on atomic energy for the layman. Written by a man who possesses the unique combination of writing ability and technical knowledge, it is first of all a story, not a treatise. At the same time it is accurate. It is the most important story of our time told in simple language by a man who has spent many years in the field of science fiction. He is the Editor of Astounding Science Fiction.

The Strange Story of the Quantum. By Banesh Hoffman. Harper & Brothers, $3.00

Easily the best account of the growth of the ideas underlying our present knowledge of atomic structure, prepared for the reader not especially trained in nuclear physics. It has taken one of the most abstruse and difficult questions—just how matter and energy are put together—and made it readable and understandable as it can be.

The Science and Engineering of Nuclear Power. Two Volumes. Edited by Clark Goodman. Addison Wesley Press, Inc., $7.50 each

These two volumes contain the essentials of a series of seminars initiated at MIT in October 1946. They provide, by far, the most valuable and usable technical material for the engineer available today. Their objective is to present the fundamentals of chain reacting systems in terms that are understandable to engineers interested in the industrial applications of nuclear energy.

Atomic Energy. By Karl K. Darrow. John Wiley & Sons, Inc., $2.00

The exciting story of the development of nuclear physics—a story climaxed by the reality of atomic energy and the atomic bomb. Told by an expert who can speak the layman's language.

Power Engineering

Combining
POWER PLANT ENGINEERING and POWER GENERATION

POWER ENGINEERING—a better title

Very few readers or advertisers will ask "Why?" this change in the name of an old established publication from *Power Generation* to *Power Engineering*.

Many of you will recall that the old name *Power Plant Engineering*, used since 1918, was changed in January 1948 to *Power Generation* as part of our plan to start the new publication, *Plant Engineering*. The *new* magazine covers the function of plant engineering in industry, a function separate and distinct from power engineering and *Plant Engineering* is the perfect title for that field. The rapid success of the new magazine is proof of the rightness of the functional analysis.

We had planned in 1947 to create two new titles, *Plant Engineering* and *Power Engineering* from the old title, *Power Plant Engineering*. However, it was decided to use *Power Generation* instead of *Power Engineering* because at the time it seemed to be more specific.

After two years it is evident that the name *Power Generation* is interpreted by many as *restrictive* rather than specific and the impression has been gained that the old publication under the new title of *Power Generation* is *narrower* in scope than *Power Plant Engineering* had been. This is not the case. It is the same magazine which for years has served the entire field of power engineering.

So the only sensible thing to do in fairness to readers, advertisers and ourselves is to go back to the title *Power Engineering* as originally planned in 1947. This title accurately describes the field and function served and indicates the continuity from *Power Plant Engineering*.

We were "right the first time" and are now doubly sure that *Power Engineering* will be the title for many years to come.

Sample copies of either or both of the above magazines are available on request.

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